Project Title: **ANALYSIS AND TESTING OF A BRIDGE DECK REINFORCED WITH GFRP REBARS**

Purpose of Proposal: A current initiative by FHWA, the Innovative Bridge Research and Construction (IBRC) Program, focuses on new materials and technologies in bridge design and construction. Under this program, a recent project awarded to the North Carolina Department of Transportation concentrates on a bridge deck reinforced with Glass Fiber Reinforced Polymer (GFRP) rebars. The objective of the proposed research project is to further advance the state of knowledge and practice on the design, construction, and behavior of GFRP reinforced concrete bridge decks.

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1. INTRODUCTION

Field applications of fiber reinforced polymer (FRP) composite materials as a means of reinforcing concrete structures is a rapidly growing area for which alternatives to steel reinforcing bars and innovative strengthening and rehabilitating approaches are currently being implemented. These methodologies have stemmed primarily due to a significant transportation-based infrastructural challenge facing engineers today, namely, the resulting deterioration of concrete bridges due to the corrosion of the internal steel reinforcement—an issue that only becomes further exacerbated upon the application of deicing chemicals.

2. BACKGROUND AND LITERATURE REVIEW

Under the Transportation Equity Act for the 21st Century (TEA-21), a 90.5% minimum support initiative to state highway agencies will facilitate better long-term planning and overall enhancement of the individual state's transportation infrastructure. As stated by Congressman, Bud Shuster, Chairman of the Committee on Transportation and Infrastructure (Harrisburg Forum), "Investment in infrastructure is now recognized as vital to all walks of life. Through TEA-21 we have the opportunity to positively affect the lives of all Americans." Because of this Act, new bridges, materials, and construction techniques are being researched and implemented to positively affect change, both in terms of durability as well as in the life-cycle costs of these systems.

Previously, transportation design engineers in the United States were reluctant to employ FRP reinforcement largely because of their perception that design and construction standards or guidelines were unavailable. Currently, however, domestic state governments and engineering associations worldwide are cooperating to standardize workable national and international design parameters and specifications (Bradberry and Wallace, 2003).

Among other research projects, El-Ghandour et al. (2003), Ospina et al. (2003), and Jacobson et al. (2004) studied the behavior of concrete slabs and decks reinforced with glass fiber-reinforced polymer (GFRP) rebars. Based on their findings and the parameters studied, it is clear that the behavior of flat slabs is governed by punching shear around the supporting column, or in the vicinity of the applied wheel loading.

3. RESEARCH OBJECTIVES

In the available literature however, little or no information is available on the continuity aspects of bridge decks subjected to simultaneously applied wheel loads applied in adjacent deck spans. In these cases, it is anticipated that in addition to the above-mentioned punching shear, flexure and one-way shear will also affect the behavior of concrete bridge decks.

To address these issues, the objectives of the proposed project is to perform material and small scale tests, test 1 full-scale (in the transverse direction) GFRP reinforced concrete deck in the laboratory, analyze the collected data, compare it to predicted behavior as well as to the data obtained from monitoring the actual bridge itself, and finally to furnish recommendations to NCDOT engineers as per the research findings.

4. RESEARCH METHODOLOGY AND ITEMIZED TASKS

a. Material Testing: This first task will involve a thorough survey of the commercially available FRP rebars. Industry accepted tests will be performed to evaluate each rebar type for durability and physical/mechanical properties. A number of such tests have already been performed by the FRP rebar manufacturers – these test data will be reviewed, and a gap analysis will be performed.

   In order to test these rebars, ACI 440 and ASTM standard test methods will be used. Several additional test methods are currently being developed by ACI 440 committee on the concrete/FRP rebar bond strength. If such tests will be required by the NCDOT TAC committee, small scale beam tests will also be performed.

b. Large Scale Laboratory Testing: A (transversely) full-scale GFRP reinforced concrete slab specimen will be fabricated and tested with the equivalent of two HS20 AASHTO truck wheel loads to simulate and impose the maximum load-effect generated by two trucks positioned side-by-side. Due to budgetary constraints, laboratory testing will be limited to a single, full-scale (in the transverse direction) specimen.

   The full-scale concrete slab specimen will have three 6'-9" spans (with a 5'-5" clear span each); four AASHTO type III beams (10'-10” in length) will be used to support the slab. The girders will be supplied by Mr. Frankie Smith, of Carolina Prestress (Charlotte, NC). Similar to actual field conditions, the slab will be constructed integrally with the girder shear connectors.

   As illustrated in Figure 1 below, this full-scale setup will allow the research team to study the slab behavior under a worst-case loading condition. In order to simulate actual tire pressure on a bridge deck, the wheel load simulator will be padded using actual rubber tire segments. The geometry of the loading setup will be decided later, based on extensive discussions with NCDOT research and bridge design engineers. Both service and ultimate loading levels will be monitored.

c. Construction Monitoring: Similar to the report prepared for the GFRP deck bridge 89-0022 (Stiller and Gergely, 2002), a detailed construction report will be prepared based on observations during the placement of the actual GFRP reinforcement and the concrete pouring of the deck superstructure.

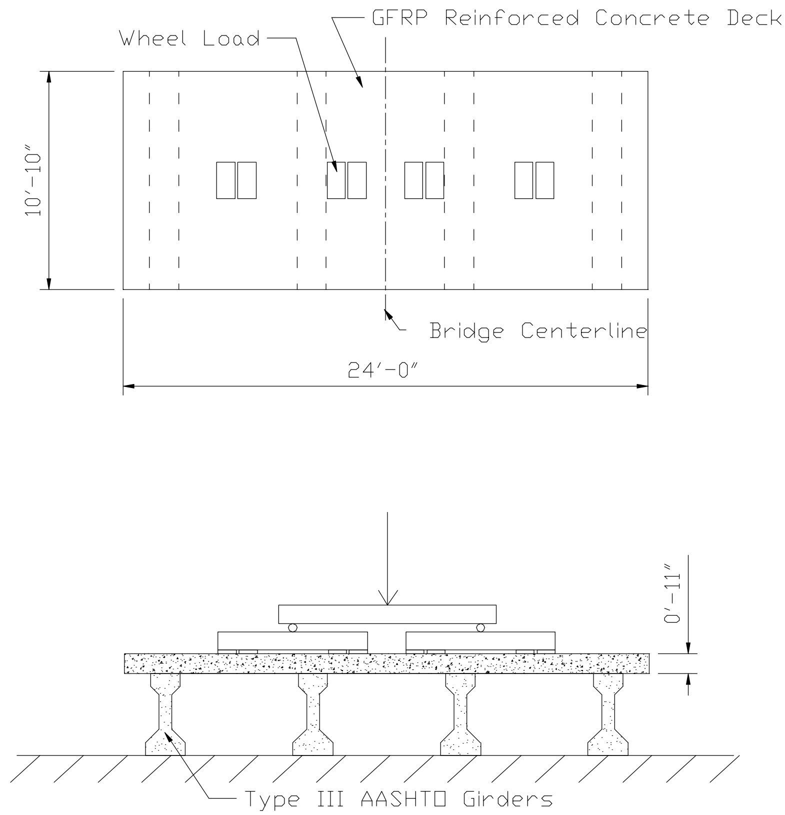

Figure 1. Sample details and test setup

d. Actual Bridge Field Testing: Prior to the concrete placement, numerous foil strain gages will be installed on the GFRP bars to compare the experimental and predicted strain values. These gages will be placed at locations of maximum positive and negative moments in the deck. In addition to these gages, strain transducers will be used to monitor the strain level on the girder and deck surfaces. Additionally, displacement transducers will be used in order to record the vertical deformations of the girders and deck as well as to locate the position of the loading truck(s) along the bridge length.

   Based on previous experience in bridge testing (Gergely et al., 2004), two types of actual truck tests will be conducted following construction and instrumentation: (i) slow (~5 mph), and (ii) dynamic (~45 mph) loading regimes. The actual loading vehicle(s) will be selected to simulate the loading of one (or two) bridge lanes at the design load level of the theoretical HS20 truck.

e. Analytical Study: Both the laboratory test results and the field test data will be analyzed and compared with predicted behavior. This will be performed using common engineering software tools, as well as simple hand calculations. In order to facilitate this comparison, the findings presented in the CFL-RD-2003/09 report by Hassan and Rizkalla (2003) will be used.

Greater emphasis will be placed on wheel load distribution factors, impact factors on the actual bridge, and the predictability of GFRP reinforced deck behavior (strain and stress levels, vertical stiffness, etc...). As mentioned earlier, the analytical study will also focus on the deck's punching (and one-way) shear and flexural response.

5. SIGNIFICANCE OF PROPOSED WORK

This project involves the first GFRP reinforced deck in the State of North Carolina. The construction report, the laboratory and field tests, and the analytical study will provide valuable information on the true behavior of this novel system. It is anticipated that the results from this project will increase the confidence level of NCDOT engineers to use alternative reinforcing materials and methods. Ultimately, corrosion resistant reinforcement will increase the life-span of bridges and structures exposed to a variety of elements, benefiting the public in general

6. IMPLEMENTATION AND TECHNOLOGY TRANSFER

Since the project will follow well established protocols, it is anticipated that no problems will be encountered with the technology transfer of the research results and recommendations (as applicable). To ensure this, the research group will be in close contact with the NCDOT research, design and maintenance engineers, updating the advisory group on the project results regularly.

7. NCDOT RESOURCES AND INDUSTRY SUPPORT

This project will involve both laboratory and field testing. Therefore, careful planning will be essential. In order to perform the proposed tasks, the following NCDOT resources and support is respectfully requested:

- Provide assistance during construction monitoring and instrumentation of the actual bridge (access to the site, field equipment, occasional manpower, etc...).
- Provide a loading truck(s) and traffic control for the duration of the bridge loading.

Additionally, in order to keep the research cost reasonable, the following industry support has been arranged by Mr. Rick Lakata, NCDOT Research group:

- The 4 Type III AASHTO girders are being provided free of cost by Carolina Prestressed, as indicated by Mr. Frankie Smith, Plant Manager in Charlotte, NC.

8. PROPOSED WORK SCHEDULE

The following schedule was prepared based on the information that the actual bridge construction and field tests will be performed in the fall of 2005. Therefore, the activities during the first fiscal year will include the basic material tests and large scale laboratory tests. During the second fiscal year the construction monitoring, bridge field testing and analytical work will be performed.

	TASKS	24 MONTHS							
a	Material Testing	x	x	x	x				
b	Large Scale Laboratory Testing			x	x				
c	Construction Monitoring					x			
d	Actual Bridge Field Testing					x	x		
e	Analytical Study			x	x		x	x	x

9. RESEARCHER QUALIFICATION

Dr. Gergely has significant analytical, field and laboratory experience with bridges and other reinforced concrete and masonry structures. In addition to a fully equipped structural laboratory and mobile data acquisition system, an experienced Laboratory Technician, one post-doctoral fellow with previous design and research experience, and a number of undergraduate students will support the proposed project. This project will also provide a unique opportunity for our students to work in an industrial and research environment.

10. REFERENCES

Bradberry, T.E. and Wallace, S. "FRP Reinforced Concrete in Texas Transportation—Past, Present, Future," Field Applications of FRP Reinforcement: Case Studies. Sami Rizkalla and Antonio Nanni (editors), American Concrete Institute, SP-215, pp. 3-20 (2003).

El-Ghandour, Abdel Wahab, Pilakoutas, Kypros and Waldron, Peter. "Punching Shear Behavior of Fiber Reinforced Polymers Reinforced Concrete Flat Slabs: Experimental Study," Journal of Composites for Construction, ASCE, v7, n3, pp. 258-265 (2003).

Jacobson, David A., Bank, Lawrence C., Oliva, Michael G., and Russell, Jeffrey S. "Punching Shear in Fiber-Reinforced Polymer (FRP) Bi-layer Grid-Reinforced Concrete Bridge Decks," TRB 2004 Annual Meeting (on CD-ROM), 21 pp. (2004).

Gergely, Janos, Lawrence, Timothy, Prado, Claudia, Ritter, Chad, and Stiller, Brad. “Evaluation of Bridge Analysis vis-à-vis Performance,” Final Report Project 2002-12, prepared for NCDOT (2004).

Hassan, Tarek K., and Rizkalla, Sami I. “Design Considerations for Continuous Bridge Deck Slabs (Project No. B-3485),” Technical Report CFL-RD-2003/09, NC State University (2003).

Ospina, Carlos E., Alexander, Scott D.B., and Cheng, J.J. Roger. "Punching of Two-Way Concrete Slabs with Fiber-Reinforced Polymer Reinforcing Bars or Grids," ACI Structural Journal, v100, n5, pp. 589-598 (2003).

Stiller, Brad, and Gergely, Janos. “GFRP Deck Project Construction Report – Bridge 089-022, SR 1627 – New Salem Rd, Union County,” prepared for NCDOT (2002).